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PREFACE

This report covers activities and accomplishments of the U.S. Grain Marketing Research Laboratory (USGMRL) from October 1, 1981, to September 30,1982 (FY 82). We continued to manage our shrinking resources economically while selecting those areas of research with maximum impact upon our regional, national, and international grain-marketing interests. Both basic and applied research have been conducted in keeping with our mission to address problems and opportunities utilizing the unique multidisciplinary capabilities among the personnel in the laboratory. The keywords in the research programs have been cooperation and teamwork; it is axiomatic that progress is made through creative contributions of each person toward common goals.

We speak of cooperation not only among personnel within the Laboratory but also with researchers in other laboratories, both within and outside the U.S. Department of Agriculture (USDA). Many collaborative efforts have been carried on with various departments of Kansas State University (KSU), such as Grain Science and Industry, Agronomy, Entomology, Biochemistry, Biology, Engineering, Animal Science, Veterinary Science, Chemistry, and Plant Pathology. Collaborative studies also have been carried out with such technical projects as NC-151 (Marketing and Delivery of Quality Cereals and Oilseeds in Domestic and Foreign Markets) and S-135 (Microbial Control of Insects).

Close cooperative communication has also been maintained with personnel of action-regulatory agencies within the USDA such as the Federal Grain Inspection Service, Food and Drug Administration, Animal and Plant Health Inspection Service, Foreign Agricultural Service, Agricultural Stabilization and Conservation Service, and the Economic Research Service. Liaison has also been maintained with laboratory personnel within the Agricultural Research Service (ARS) including those of the Western and Northern Regional Research Centers, the Stored Product Insect Research and Development Laboratory, and the Soft Wheat, Hard Red Spring and Durum Wheat, and Western Wheat Quality Laboratories. We have coordinated efforts with various institutes, trade associations, and individual companies interested in and concerned with all phases of grain marketing. These represent a wide geographical distribution and include, among many others, the American Institute of Baking, U.S. Wheat Associates, various State Wheat Commissions, and the National Grain and Feed Association.

The collaborative and cooperative interactions are the direct result of the demonstrated creativity and accomplishments of scientists of the Laboratory and their support personnel. Their recent advances are tabulated in the form of scientific, technical, and popular articles, publications, and oral presentations listed in this report. Recent progress in grain-marketing research is described in this report, highlights of which follow in this Preface.

Freeze-fracture electron microscopy was shown to be a powerful tool in explaining protein changes as they affect dough mixing, fermentation, and baking. Comparing the structure of high-protein amphiploid wheat with its progenies and with hexaploid wheat showed the subaleurone region to have the greatest variation in size and number of starch granules and in appearance of protein matrix.

Analysis for ash, protein, and mineral contents of 44 cultivars and progenies grown at 23 locations over 2 crop years indicated locational effects to be greater than heritable factors on compositional ranges. Zinc, phosphorus, magnesium, potassium, and calcium contents were related to protein content and with each other to various degrees among locations or cultivars and progenies, depending on the basis for computation. The correlations for zinc with protein for cultivar and progeny composites, and for copper with protein among locations, were particularly significant.

Extractability of free lipids from a good and poor breadmaking flour did not differ significantly; however, extractability of lipids from acid solubilized and neutralized glutens differed for the two flours. The pH of gluten solubilization affected the ratio of bound to free lipids from solubilized and neutralized glutens.

Four lipid solvents extracted most lipids from flour and least from the dough containing greatest quantity of added cysteine. Less lipids were extracted from

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doughs than flour. The results are attributed to lipid binding to protein during mixing and by the dissociation of gluten in protein by the addition of cysteine. The increased lipid binding to protein by adding cysteine may contribute to an increase in loaf volume of flours with long mixing-time requirements.

Instrumentation was developed whereby the colorimetric determination of alpha-amylase activity on grain was used to estimate the extent of sprouting. The colorimetric test has been shown to be applicable to other cereals as well as wheat. Results of the test are highly correlated with falling number and amylograph assay data.

Propionic acid is often added to damp corn as a preservative. The quantitation of this compound could be carried out directly on a very sensitive basis through gas chromatography, following homogenization in water containing *n*-butyric acid as an internal standard. The method is sufficiently sensitive so that propionic acid content can be determined on a single kernel.

Fungal invasion of sorghum hybrids began at or soon after maturity as determined by ergosterol content or mycological assay. These analytical procedures provided better indices of infection than visual ratings of weathering and discoloration. Fungal infection in grains that did not appear to be weathered or discolored was readily detected by ergosterol and plating assays. We also found that ergosterol content was superior to chitin in determining ergot contamination in barley, rye, and other cereals.

Chemical and histological studies were initiated on the scab organism *(Fusarium roseum)* and on scab damage to wheat.

A major survey has revealed severe and widespread resistance to the insecticide malathion in the red flour beetle on farm-stored grain. Measurable tolerance occurred in 31 of 36 strains tested, representing 10 grain-producing states. Fifteen strains were tested further, and all achieved resistance levels of greater than twentyfold after only one generation of selection. Significant resistance was also found in the lesser grain borer. This kind of information is an essential prerequisite to intelligent decision making regarding pest control strategy. We found that malathion resistance, which is widespread in red flour beetle populations in the United States, is controlled by a major autosomal semidominant gene. The gene has been located on linkage group VI.

Fundamental studies designed to develop a complete understanding of the chemistry and toxicity of entomocidal protein produced by *Bacillus thuringiensis* have led to the isolation and cloning of the gene that codes for the toxic protein. One recombinant phage-produced antigenic protein that was toxic to *Manduca sexta* larvae, proving that the structural gene for toxin synthesis could be genetically moved from one organism to another. The cloned gene appeared to be chromosomal in origin although an identical toxin gene was located in a 45-kilobase-pair plasmid.

Insect tissue cells grown in laboratory culture have been found to exhibit a response to *B. thuringiensis* entomocidal protein, which is similar to that observed in digestive tract tissue after ingestion by larvae of lepidopteran insects. The cytolytic reaction retains normal larval specificity between sensitive species and is quantitative. Thus, cultured insect cells can be used as an alternative bioassay system for *B. thuringiensis* toxicity, which is more rapid and equally as sensitive as larval mortality bioassay. The *in vitro* system also offers the potential for the study of toxin mode of action in a cellular system at the molecular level. Studies are underway to determine the biochemical effects of *B. thuringiensis* entomocidal protein on insect cell physiology *in vitro*.

An insect growth regulator, ethyl *p*-phenoxyphenoxygethyl carbamate (Ro13-5223), was found effective as a grain protectant in the field. The results are being used to support an application for an experimental use permit for stored grain.

Thirteen vertebrate peptide-like hormones were localized by immunohistochemical methods in specific brain cells and nerve fibers to the corpora cardiaca and corpora allata. The peptides include insulin, somatostatin, glucagon, pancreatic polypeptide, secretin, vasoactive intestinal polypeptide, glucose-dependent insulinotropic peptide, gastrin, enkephalin, α- and β-endorphin, substance P, and calcitonin. The results indicate that the nervous and endocrine components of animals cannot be separated at the evolutionary level of protostomian invertebrates and, instead, the components appear to belong to the same regulatory system.

In a national survey of more than 8,000 farm bins across 27 states, scientists of USGMRL found that grain stored on the farm contains a broad spectrum of storage pests that are often present in damaging numbers. High levels of insect activity corresponded directly to the infrequent use of preventive or remedial control measures. The incidence of insects increased with increased grain moisture, and average test weights per bushel were lower in infested grain than in uninfested grain. Grain with high mold invasion also contained increased numbers of insects, particularly among those species that prefer high moisture conditions or feed on molds. Storage molds were much more prevalent in corn than in wheat, the difference being attributed to higher

storage moisture contents for corn.

Cooperative wheat quality evaluations with breeders in the hard red winter wheat region were carried out to maintain the high milling and baking qualities prevalent among present commercial cultivars. About 37 percent of the approximately 350 entries submitted by breeders were found to have satisfactory processing quality. Genetically high protein content, a desirable trait, was also found among some of the lines. In addition to the above, about 60 percent of almost a thousand early generation entries screened for quality were adjudged to have good quality or genetically high protein content or both. Three new hard red winter cultivars released recently include 'Dawn' (developed in Colorado and released in South Dakota), 'Rita' (South Dakota), and 'Arkan' (Kansas). Genetic variability for high protein content in 'Lancota' was great enough to enable the selection of higher protein lines than the original cultivar outside its area of development.

Nuclear magnetic resonance (NMR) techniques applied to the characterization of thionins indicated five proteins from barley and wheat to have similar conformational features in deuterium oxide (D_20). In addition, their secondary and tertiary structures were similar to those of crambin, a hydrophilic protein from *Crambe abyssinica*. Evidence was found that although thionins have a folded conformation, they are structurally flexible polypeptides.

Purothionin from *Triticum monococcum* had an amino acid sequence identical with that of β-purothionin from common wheat. We developed a procedure for the hydrolysis and determination of amino acid composition by high performance liquid chromatography (HPLC) of proteins from cereal grains. The sensitivity of the analysis (10 pico moles of commonly occurring amino acids) permitted determination of the amino acid sequences of small quantities of cereal thionins.

The polyacrylamide gel electrophoretic (PAGE) pattern of the gliadins of a wheat variety was independent of variations in kernel size, shape, color, or frost damage. In a mixture of two cultivars, as little as 5 to 10 percent of one can be detected by PAGE. We identified wheat cultivars by comparing their computerized PAGE bands with those of known cultivars.

A 100-g analytical, optimized, straight-dough breadmaking test researched and developed more than 40 years ago by the Laboratory is still as practical and useful today as when originally developed. Changes have been made to make it applicable to such changing techniques as substituting ascorbic acid for potassium bromate, eliminating nonfat dry milk, eleminating sugar in high-protein formulas, shortening fermentation time, and proofing to height as well as to time.

Experiments on water mobility in doughs and bread, using pulsed NMR, showed that, in doughs, flour associated more strongly with D_20 than water, that varying the ratio of D_20 and H_20 had no effect on deuteron relaxation, and that hard and soft wheat flour showed increases in deuteron relaxation with moisture content. Bread staling was found to be due to decrease in water mobility and increase in binding.

A transfer strategy was developed for a batch, in-bin, grain-drying system operable at relatively high airflow rates and at grain depths of 5 to 7 ft. A solar collector surface area equal to the bin floor area provided enough supplemental heat to reduce grain moisture 1 percent below that removed solely by ambient air. The solar heat, in-bin, drying systems reduced the energy input requirement by about 10 percent. The transfer strategy provides a means by which one can eliminate the problem of nonuniform distribution of airflow caused by fine particles in wet corn. The strategy also prevents overdrying, increases drying capacity, and reduces mold growth. In addition, it permits earlier harvesting.

Efforts were continued to improve the performance of a wind-powered, grain aerator of novel design that was installed in an 18-ft diameter bin.

Animal fat, silicone fluid, and lecithin applied to grain were found effective in controlling dust generated during grain handling. Dust explosion research in FY 82 involved both experimental and theoretical efforts toward modeling grain dust explosions in a 20-L spherical chamber. Fault Tree Analysis was used to develop a model for predicting the risk of dust explosion in grain-processing and handling facilities.

The velocity of grain flowing in a stream is directly related to the extent of damage it incurs while moving. A sensor with light-emitting diode and phototransistor pairs, developed at USGMRL, was successfully used to measure the velocity of a flowing stream of corn.

The applicability of research findings to the market place is often influenced by the economics involved. Cost-benefit ratio can be a major consideration in research even during the planning stage. The presence at USGMRL of two research economists who are members of our sister agency, the ERS, provides us with consulting expertise that adds another dimension and perspective to our efforts.

Our scientists continue to be recognized for their research excellence through grants and awards. The Competitive Grants Office of USDA gave a grant for the study of insect control through chitin degrading enzymes, the National Science Foundation approved one on the regulation of tyrosine metabolism for cuticle tanning (cooperatively with the KSU Department of

Entomology), and ARS granted one on the study of scab in wheat (cooperatively with the KSU Department of Grain Science and Industry). We also received a grant from the Competitive Grants Office to conduct studies on formation of cereal grain protein bodies. Laboratory Director Y. Pomeranz was awarded the William F. Geddes prize for meritorious service to the American Association of Cereal Chemists. Pomeranz also was awarded the prestigious von Humboldt Senior Fellowship award, which has enabled him to conduct personal research for 1 year at Detmold, West Germany. W. T. Yamazaki is acting director and acting location leader in the absence of Pomeranz.

The high scientific standing of many of our personnel is demonstrated through requests to serve in many capacities. Our scientists serve on editorial boards of highly regarded technical journals; they organize and participate in symposia, workshops, and short courses; they deliver invitational lectures, edit books and monographs, and participate in research planning sessions; they serve on personnel evaluation committees, and they are involved in societal affairs in many ways.

The laboratory was favored by hundreds of visitors from most states of the nation and more than 50 foreign countries. Government officials, trade representatives, research scientists, educators, students, farmers, millers, and bakers were represented among the visitors. Space does not permit the listing of individuals or groups, except to indicate that we were happy to cooperate with many groups, including the KSU Food and Feed Grain Institute and International Grains Program, the Kansas Wheat Commission, the U.S. Wheat Associates, and the Group for Assistance on Systems relating to Grain After Harvest.

Wm. T. Yamazaki
Acting Director, USGMRL

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GRAIN STRUCTURE, COMPOSITION, AND CHARACTERIZATION UNIT

Scientists in this unit conduct investigations to (1) determine relation of grain structure to storage, handling, and utilization; (2) identify composition of cereal grains in relation to storage, handling, utilization, and nutritive value; (3) develop the use of enzymes to determine composition, structure, storability, and damage during handling of cereal grains; (4) develop tests on grain quality for use in plant-breeding programs, quality control during processing and storage, and action and regulatory agencies during marketing; and (5) identify, control, and eliminate mycotoxins from cereal grains.

Grain Structure

We study cereal grains and processed grain products using various microscopic techniques, including light and scanning and transmission electron microscopy. These studies are designed to correlate grain structure with market quality investigations conducted in other research units in the Laboratory.

Structure of a New High-Protein Amphiploid Wheat.—The structure of a new high-protein amphiploid wheat was compared by light and electron microscopy to its diploid and tetraploid progenitors and to a commercially grown hexaploid hard red winter wheat grown under the same conditions. Appearance and protein content of the central starchy endosperm were similar in all the cultivars. The subaleurone region showed the greatest variation in both number and size of the starch granules and in the appearance of the storage protein matrix. The high-protein amphiploid had the largest subaleurone region with the least number of type A and B starch granules.

Evaluating Wheat-Scab Infection.—We began a study of the degree of kernel infection by wheat scab using a variety of light and electron microscopic techniques. In severely infected grains, we found that starch granules were highly modified. Their appearance suggested enzymatic digestion. The wheat storage proteins and lipids were found to have been completely removed by the fungus. Specific stains for proteins showed that all of the protein associated with severely infected kernels was located in the fungus. Lightly infected wheat was completely permeated by the fungus also, however, most of the fungal hyphae were located in the pericarp and aleurone layer. The microscopic data suggest that lightly infected kernels can be milled to remove the outer, heavily fungal-contaminated bran layers. The inner starchy endosperm will retain the fungal hyphae.

Endosperm Protein Matrix Formation in Wheat.—The deposition of protein into vacuoles in the starchy endosperm of hard red winter wheat was studied using transmission electron microscopy and enzymatic digestion of thin sections. Protein bodies that formed in the cytoplasm were transported to the central vacuole, where the protein body membrane and tonoplast fused and deposited the granule of protein into the vacuole. The protein granules in the vacuole enlarged by three mechanisms: addition of membranous vesicular material of various types, addition of flocculent material, and fusion of the granules with other newly deposited protein granules. The fusion process occurred rapidly 17 days after flowering and resulted in converting the spherical protein granules into irregularly shaped protein masses that eventually became the matrix protein. Enzymatic digestion of thin sections revealed that the contents of dense-cored Golgi vesicles and protein bodies were susceptible to protease VI and pepsin but not to α-amylase. The vacuolar protein granules were almost completely digested with protease VI and pepsin. The only undigested regions were peripheral, densely stained inclusions thought to be the last added protein.

Novel Method for Studying Bacterial Membrane Mobility.—We developed a novel method to study membrane mobility during sporulation in *B. thuringiensis*. The method involved labeling specific branched chain end groups of *iso*-even fatty acids in *B. thuringiensis* with carbon 13. The end groups were labeled, using D,L-(3,4^{13}C) valine as a precursor chain initiator and the bacteria's metabolic pathways to specifically incorporate the ^{13}C carbon into *iso*-even fatty acids. Nuclear magnetic resonance was then conducted on whole live cells during growth and sporulation. This study showed that the end-group mobility decreased so dramatically during sporulation that, in the mature spore, the carbons were no longer mobile (in NMR terms). This study represents the first time a branched chain fatty acid has been specifically labeled with carbon 13 and then that the mobility of these carbons followed in intact live cells. This study also reports for the first time the dramatic dynamic molecular changes that can occur in bacterial membranes during growth and sporulation.

Grain Composition

In these studies, our approach is to determine protein, lipid, mineral, and carbohydrate contents and interaction products among grain components as they relate to storage, handling, utilization, and nutritional value. The studies are designed to provide information on composition of cereal grains to other units in

USGMRL in investigating the effects of composition on handling, storage, end uses, nutritional value, and development of quality tests.

Lipid Extractability of Cysteine-Treated Dough.—Studies on lipid extractability of cysteine-treated dough showed that amounts and compositions of lipids varied with extractants and depended on whether extractions were made from flour or doughs. About 59 percent less free lipids were extracted from control dough and about 77 percent less from dough containing 121.0 parts per million (ppm) cysteine than from flour. Our research shows that a substantial decrease in lipid extractability resulted from an increase in lipid binding to proteins during mixing and, further, by the dissociation of glutenin protein from the addition of cysteine; disaggregated proteins, presumably, supplied more binding sites for free lipids. Addition of cysteine and resultant increased lipid binding to proteins during mixing may, in part, contribute to an increase in bread volume of flours with long mixing requirements.

Lipid Extractability from Poor and Good Breadmaking Glutens.—The glutens of good (C.I. 12995) and poor (KS501099) breadmaking flours were solubilized at pH 3.0 to 5.5 with dilute lactic or acetic acid, and solubilized glutens (SG) were precipitated (PG) by raising pH to 6.1 with sodium carbonate (Na_2CO_3). Amounts of free lipids in SG increased as pH of gluten solubilization decreased from weakening of binding by increasing acidity. There were much more free lipids and less bound lipids in SG from KS501099 than in SG from C.I. 12995. Extractability of free lipids in PG was substantially lower than in SG. Ratios of bound to free lipids ranged from 7 to 25 in PG and from 1 to 6 in SG. Those ratios in PG from C.I. 12995 and KS501099 varied and were affected by pH of gluten solubilization.

Mineral and Protein Contents in Hard Red Winter Wheat.—Ash, protein, and mineral contents were determined for 25 cultivars and progenies of hard red winter wheat grown at 23 locations in the Great Plains in 1973 and for 19 cultivars in 1979. Ranges of all components were wider for location composites (across cultivars and progenies) than for cultivar and progeny composites (across locations). When components were expressed as percent of sample, eight correlation coefficients were statistically significant (in both years) for the cultivar and progeny composites (ash with Zn and P; protein with P, Mg, and Zn; Zn with P and Mg; and Cu with P); four were significant for the location composites (ash with P and Mg and protein with Ca and Mg). When mineral components were expressed as percent of ash, the significant correlations were Zn with protein, K with P, and Mn with Mg for the cultivar and progeny composites and Ca with protein for the location composites. The only significant correlations irrespective of how mineral content was expressed were Zn with protein for the cultivar and progeny composites and Ca with protein for the location composites.

Use of Enzymes

Enzymes are used to determine composition (proteins, carbohydrates, lipids, glycolipids, lipoproteins, and glycoproteins) and nutritional value of cereal grains, including availability of nutrients and their modification during handling, storage, and processing. Enzyme activity is assayed to determine grain quality at sprouting and deterioration during handling and storage. Studies are designed to provide information on the chemical composition (as determined by enzymatic methods) and on levels of specific enzymes directly related to quality. The information is used collaboratively among units at the laboratory to investigate various quality characteristics important in the marketing of grain and to develop testing methods for those quality factors. Enzymes are used to determine, selectively and specifically, trace amounts of nutrients and contaminants in mold-, insect-, or rodent-infested grain.

Alpha-Amylase in Grains.—Use of enzymes to determine grain quality includes the development of a colorimetric assay for alpha-amylase, which can be used throughout the marketing process to determine extent of sprouting in wheat. In addition to wheat, the test has been shown to be applicable to other cereals as well, including rye, barley, millet, oats, and triticale. Collaborative tests using this method were conducted by 24 scientists around the world, and they found that the procedure is highly correlated with falling number and amylograph assays over a wide range of alpha-amylase activity. An instrument was developed that is commercially available and provides an exceptionally simple and rapid means of determining alpha-amylase content. Further collaborative work showed the procedure to be an accurate and reliable tool for grain quality evaluation. The procedure has also been adopted to provide a means of assaying for alpha-amylase activity in barley malts. This colorimetric assay has recently been adopted as an official method of the American Association of Cereal Chemists.

Quality Tests

The information developed in the Grain Structure, Composition, and Characterization Unit, and in other units at USGMRL, is used to develop tests for evaluating end-use properties of new wheat cultivars,

determining changes that occur during storage of grain, and evaluating grain in marketing channels.

Hardness Tests in Cereal Grains.—Grain hardness in wheats from various classes, resilience of corn and susceptibility to breakage, degree of milling rice, and germinability of malting barley were determined. Hardness was determined in five series each of 6 to 20 corn samples. The samples included (1) commercially grown hybrid dent corn, (2) commercially grown corn that varied in percentage of amylose and amylopectin (dent, waxy, high amylose), (3) dent corn (a mixture of commercial hybrids) dried under various commercial conditions, (4) experimental lines of flint and dent corn, and (5) isogenic pairs of flint and dent corn. The samples were characterized and tested for brittleness (Stein breakage tester) and hardness (density and particle size distribution and weighted average and near infrared (NIR) reflectance of ground corn). Effects of moisture content and conditions of hardness measurements were determined, and effects of composition were evaluated. The three methods of hardness determination (density, particle size, and NIR reflectance) for the five groups of samples were highly correlated.

Hot-Pasting Abilities of Wheat Flours and Starches.—Hot-pasting abilities of flours of 68 wheats of U.S. origin were compared with a Brabender amylograph in the absence of amylase activity. Starches prepared from eight of the wheats with minimal granule damage were examined similarly, and their susceptibility to amylase attack was determined. The inherent hot-pasting abilities of flours of U.S. wheat cultivars in the absence of amylase were similar in range to those previously determined for New Zealand wheat cultivars. Flours from soft and club wheats and one sample of durum wheat had poor pasting ability. A marked seasonal effect on pasting was observed. Part of the variation in pasting can be explained by differences in protein contents and starch damage. Susceptibility of starch granules to attack by fungal amylase during the determination of starch damage was not correlated significantly with susceptibility of starch pasting to attack by sprout amylase.

Gas Chromatographic Determination of Propionic Acid.—A simple, rapid, gas chromatographic procedure was developed for determining propionic acid added as a preservative to corn. The sample to be analyzed was homogenized in water containing *n*-butyric acid as an internal standard. We analyzed the resulting aqueous solution directly by gas chromatography, thus eliminating any distillation or solvent-extraction step. The method was sufficiently sensitive to allow an analysis to be performed on a single kernel. Propionic acid at a concentration of less than 1 ppm could be determined in the aqueous extract. In addition, we devised a rapid procedure employing an indicator for detecting the presence or absence of the acid in individual kernels.

Mycotoxins

In mycotoxin research, we develop analytical procedures, preferably suitable for use in grain-marketing channels; for detecting specific fungal components as measures of extent of invasion, mycotoxins, and other fungal metabolites; and for identifying fungi-grain interrelationships that may regulate invasion of particular grain types, varieties, or hybrids by specific genera or species of fungi. The approach used in these studies is to apply optimized extraction and chromatographic techniques and to simplify and make more effective initial extraction, cleanup, and final detection steps. Metabolites are evaluated as measures of fungal invasion on grains and are compared with mycological and such other tests as discoloration, germination, fat acidity, and odors. We also investigate differences in susceptibility to invasion by fungi among grain types, varieties, or hybrids.

Preharvest Fungal Invasion in Sorghum Grain.—A study of sorghum hybrids harvested at 12 weekly intervals showed that fungal invasion, as measured by ergosterol and mycological assays, began at or very soon after physiological maturity. Although visual ratings of weathering and discoloration of sorghum grain correlated significantly and positively with ergosterol content, the ratings did not adequately indicate extent of fungal invasion. Sorghum grains that did not appear weathered or discolored had differences in extent of fungal invasion that were detectable by ergosterol and whole seed plating assays.

Relation Between Ergot and Ergosterol Content in Grains.—In a study of ergot contamination in barley, rye, and other grasses, we found that ergot would contribute more significantly to the ergosterol content than to the chitin content of grains. Certain ergosterol-related fungal metabolites, which were produced by many fungi, were also found in ergot sclerotia.

Determining Ergosterol in Rice.—We devised a method to measure ergosterol in rough rice that requires simple equipment and involves extraction, purification by thin-layer chromatography (TLC), and quantitation by ultraviolet spectroscopy. When rough rice was stored at 20 percent moisture and 35°C until dry matter loss (DML) reached 0.6 percent, ergosterol level in the grain increased in proportion to DML. It appears that the extent of fungal invasion in stored

rough rice can be followed by ergosterol analysis using this TLC method.

Mycotoxins from *Fusarium* spp. in Scabby Wheat.—Because of wet weather in May and June, some of the 1982 winter wheat crop contained an unusual amount of wheat scab. Scab is caused by fungus infection (*Fusarium* spp.) of developing wheat kernels. We cooperated with KSU's Extension Service, Grain Science and Industry Department, Animal Science and Industry Department, and Veterinary Medicine in studies of geographical location, milling and baking properties, mycotoxin occurrence, and toxicology of scabby wheat. Several of these studies are still in progress.

BIOLOGICAL RESEARCH UNIT

The Biological Research Unit is concerned with fundamental and applied biology of insects and microorganisms that infest stored grains and cereal products. Insects and microorganisms are the principal kinds of organisms that adversely affect grain quality. Insect and microbial activity in stored grains decreases germinability, discolors part or all of the seeds or kernels, causes weight loss, reduces nutritional value, produces heat, and increases moisture. Heat and moisture, in turn, bring about physical, chemical, and physiological changes in the grain. Some insects feed on whole grain, others on broken kernels, thereby increasing the percentage of broken kernels and dockage. Some microorganisms produce toxins that are injurious to man and to domestic animals. Grain and cereal products also are subject to insect and microbial infestation, damage, and contamination while in the marketing channels. The Federal Government, food storage, transportation, processing industries, and the consumer suffer large monetary losses from grain insects causing damage and downgrading and making the products unfit for human consumption. The presence of insects and the damage done by them affect us adversely in the highly competitive foreign market.

Another cause for concern in relation to foreign trade in grain is that pesticide and fumigant residues are receiving increasingly critical scrutiny in many parts of the world. These residues also are of concern for the domestic market. Urgently needed are more acceptable and effective methods for preventing insect damage and contamination during storage, handling, processing, packaging, transportation, and retail distribution. The need is critical for effective pesticides and application methods that can be used in our domestic and foreign markets without leaving objectionable residues. Even more desirable is the development of effective preventive and control measures using biological, physical, mechanical, or other nonchemical means that would reduce or completely eliminate the use of pesticidal chemicals.

The primary mission of the Biological Research Unit is to gain adequate knowledge of insects and microorganisms and their storage environment to develop appropriate techniques and methods of pest management under experimental and practical conditions. Research is divided into the following areas.

Insect Biochemistry and Physiology

Our goal is to understand the growth and development of insects in biochemical terms and to identify metabolic processes that are potential targets for new pest control agents. The program includes basic research in insect biochemistry, endocrinology, toxicology and morphology, and applied research in developing biorational materials that inhibit specific aspects of the insect's physiological and behavioral development. Chemicals receiving special attention are insect growth regulators that act as hormone mimics or antihormones and compounds that disrupt cuticle biochemistry.

Insect Growth Regulators Used for Control of Stored-Grain Insects.—We continued testing insect growth regulators (IGR) for activity against stored-grain insects. A carbamate-type IGR that exhibits juvenile hormone activity (ethyl 2-p-phenoxyphenoxy ethyl thiocarbamate) controlled stored-grain beetles and moths in both laboratory and field tests. A malathion-resistant strain of the Indianmeal moth was also susceptible to the IGR. Field testing of this material is currently in progress.

New Metabolite Identified That Participates in Insect Cuticle Sclerotization.—N-β-Alanyldopamine was identified as the major tyrosine metabolite in hemolymph and cuticle during sclerotization in insect species representing several orders. The catecholamine appears to be the main precursor of tanning chemicals at certain developmental stages. This discovery is a major contribution to the entomological research and teaching literature.

Insect-Molting Enzymes Purified and Characterized.—We continued to study enzymes that enable insects to molt their exoskeleton. An exochitinase was purified from molting fluid and characterized physically, chemically, and kinetically. The enzyme digests chitin, the major structural polysaccharide in cuticle. It is highly proficient at hydrolyzing

chitin oligosaccharides and is responsible for catalyzing the latter stages of chitin depolymerization. We are now trying to develop inhibitors of this enzyme that would disrupt the molting process.

Insulin-Like Peptide Purified from Insect Tissues—We extracted and purified insulin-like peptides from insect hemolymph and royal jelly. They were similar to vertebrate insulin in solubility, chromatographic behavior, antigenicity, biological activity, and chemical composition. The results demonstrate that insect insulin and vertebrate insulin are structurally related and add to the evidence for the presence of similar peptide hormones in vertebrates and invertebrates.

Nonhistine Chromatin Protein That Binds Single-Strand DNA Purified from Insect Cell Line.—We compared nonhistine chromatin proteins from an insect cell line with similar proteins from vertebrate tissues and found a rather high molecular weight protein with unique properties that preferentially binds single-strand DNA. The results add to the information that describes the functions of this very important but heterogeneous class of nuclear proteins.

Seed Extracts Screened for Ability To Inhibit Guanylate Cyclase in Leukemic Cells.—Leukemia is a disease characterized by elevated levels of cyclic guanylate monophosphate. We screened 10 cytotoxic plant extracts for preferential inhibition of the soluble guanylate cyclase from leukemic cells and found two that were effective, one from the bitter melon, *Momordica charantia,* and the other from Lawson's cypress, *Chamaecyparis lawsonianna.* The potential of these extracts for use in leukemia chemotherapy is currently under study.

Grain Resistance to Storage Insects

Grains can be subjected to long-term storage, mainly because of their natural storability. Storage procedures utilizing moisture, temperature, and dockage control, plus grain turning and frequent inspections, are able to protect grains in storage because they preserve the natural storability of grains. This natural storability is evidence of general resistance of grains to quality loss. In resistance research, we develop procedures to determine the role of the factors involved in this natural storability that help prevent or decrease loss through insect attack. The approach of these studies is to determine the relative reistance or susceptibility of currently grown or newly developed cultivars to attack by stored-product insects. For resistant or highly susceptible grains, we try to determine the causes of resistance or susceptibility.

Role of Kernel Coating and Bran Layers in Resistance of Wheat to Rice Weevils.—Previous studies showed that high ergosterol levels in wheat kernels are related to rice weevil oviposition with resultant progeny increases. Analysis of grains containing ergosterol showed that the husks of the grains contained up to 18 times the amount of ergosterol recovered from either the whole grains or the pearled grains. Ergosterol levels in the bran were related to the amounts recovered from the whole grains. Where whole grains were tested, the grains with the highest ergosterol levels produced more rice weevil progeny. Scalping of the grains enhanced progeny production.

Hard Red Winter Wheat and White Spring Wheat Crosses.—The infestibility of 13 selections of hard red winter wheats and white spring wheat crosses were evaluated against rice weevil. Samples tested were made up of composites from three locations in Kansas. No variation could be found in the susceptibility of these samples. This conforms to former studies where composite samples have been used. The compositing of samples from different locations removed differences that may be present or evident when samples are separated by location.

Grain Dust Production by Insects

Studies are conducted in conjunction with the Engineering Research Unit on the production of dust by stored-grain insects. The studies are designed to characterize dust produced by the major stored-grain insects as to particle size, quantity, composition, and explosibility. Also studied is the manner in which the insects produce this dust as a part of their feeding.

Residual Grain Dust Utilization by Flour Beetles.—Previous studies showed lesser grain borer and rice weevil produced significant amounts of dust as they developed populations. Fine dust (particles less than 5 μm) from these two insects was used to coat wheat kernels. One hundred kernels of wheat retained a load of lesser grain borer dust ranging from 17.98 to 28.21 mg and a load of rice weevil dust ranging from 39.68 to 47.61 mg. The kernels retained most of these loads even after repeated shakings inside a screen cylinder. Flour beetles, placed on these grains, removed all of the dust particles and left the grains appearing much as they did before dust treatment. Flour beetles placed on whole grains, with and without dust loads, were able to start populations more easily in the fine dust-treated cultivars. This would explain why normal dockage removal procedures may not lower or prevent flour beetle population increases. The residual dust load from rice weevil and grain borer feeding consists almost entirely of grain material.

Evaluating and Improving Chemical Pesticides

Research is directed toward establishing the effectiveness and stability of insecticides as grain protectants, bin treatments, and surface applications. Studies include the influence of biological, chemical, and physical factors on insecticide effectiveness, spectrum of activity, and residue stability. These studies specifically address the problems posed by decreased insecticide stability under high moisture and temperature conditions. Tests are conducted in the laboratory, in small bins, and in farm-type bins.

Candidate Grain Protectants.—Laboratory bioassays conducted over 6 months showed that compounds UC-70480, UC-62246, Bioresmethrin, and synergized pyrethrins were more effective than the standard malathion treatment for the control of the lesser grain borer, but malathion was more effective for the control of the confused flour beetle. Small bin studies with Reldan, Actellic, and malathion indicated that a bin wall treatment and a surface treatment helped reduce insect populations within the grain mass.

Avermectin for Control of Stored-Grain Insects.—Avermectin, a novel, natural product insecticide, showed potent, long-lasting activity against a broad spectrum of stored-product insects. Ten to 60 parts per billion (ppb) gave 50 percent control of both adults and progeny of the rice weevil, lesser grain borer, and sawtoothed grain beetle on whole kernels of wheat. For the Angoumois grain moth, 100 percent suppression of progeny occurred at 20 ppb. On ground wheat medium, 50 percent suppression of red flour beetle progeny occurred at 0.1 ppm and 50 percent suppression of Indianmeal moth progeny occurred at 0.3 ppm. Avermectin residues proved to be very stable. Some samples of treated wheat held at 80°C and 60 percent relative humidity for as long as 6 months showed negligible loss of biological activity at doses as low as 0.1 ppm.

Insecticide Resistance in Insect Pests of Stored Grain

Research in the insecticide toxicology laboratory is designed to (1) monitor the extent and severity of insect resistance to insecticides currently in use on stored grain in the United States, (2) assess cross resistance to candidate grain protectants with potential for registration and future use, (3) elucidate biochemical and genetic mechanisms for the most prevalent type(s) of insecticide resistance, (4) screen novel classes of chemicals to reveal new types of candidate grain protectants, and (5) analyze insect grain interactions that may confer tolerance to insecticide treatments.

Survey of Malathion Resistance in Insect Pests of Stored Grain in the United States.—We completed the study that was initiated in 1981. More than 100 strains of the red flour beetle *(Tribolium castaneum),* lesser grain borer *(Rhyzopertha dominica),* rice, granary and maize weevils *(Sitophilus* spp.), flat and rusty grain beetles *(Cryptolestes* spp.), and sawtoothed and merchant grain beetles *(Oryzaephilus* spp.) were collected from grain bins on farms in 14 grain-producing states. These were screened for resistance to malathion by the discriminating dose technique, using impregnated filter papers. Measurable tolerance occurred in 31 of 36 strains of *Tribolium*, 11 of 13 strains of *Rhyzopertha,* 7 of 22 strains of *Sitophilus,* 5 of 42 strains of *Cryptolestes,* and none of 13 strains of *Oryzaephilus.* Resistance was widespread and severe only in *T. castaneum.* Fifteen of the strains were tested further, and all achieved resistance levels of $>$ twentyfold after a single selection. Resistance in this species was largely or completely suppressed by the carboxylesterase inhibitor, triphenlyphosphate, in every case. Resistance levels were also significant in the lesser grain borer but were only marginal in *Cryptolestes* and *Sitophilus.*

Gene for Malathion Resistance Located in the Red Flour Beetle.—One of the resistant strains of the red flour beetle detected in the survey was analyzed in detail. The strain was 73-fold resistant to malathion and was highly cross resistant to phenthoate (x 53) but not to structurally dissimilar carboxylate esters nor to any of a variety of other organophosphates, carbamates, chlorinated hydrocarbons, or pyrethroids ($\leq$x 2.7). Malathion resistance *(Rmal)* was inherited as a simple autosomal semidominant trait. Linkage analysis showed *Rmal* to be located on group VI, 24.6 map units from the visible mutant marker "Microphthalmic."

Metabolism and Fate of Stored-Grain Protectants

Research in this area is designed to investigate the effect of various biotic and abiotic factors on the metabolism of stored-grain protectants. These basic studies involve the characterization and quantitation of ^{14}C-insecticide metabolites as well as the quantitation of ^{14}C-volatiles and unextractable residues.

Effect of Dockage on ^{14}C-Malathion Metabolism.—The metabolism of ^{14}C-malathion in whole wheat containing increasing levels of dockage (ground grain) was investigated. The total quantity of radiocarbon recovered in the dockage fraction increased significantly both as the ratio of dockage to whole grain increased and as the incubation time increased. A large proportion of the radiocarbon recovered in the dockage fraction was in the form of unextractable

residues. The recovery of volatile ^{14}C-compounds decreased as the proportion of dockage in the grain increased.

Effect of Storage Fungi on ^{14}C-Malathion Metabolism.—The degradation of ^{14}C-malathion was investigated in stored corn and wheat inoculated with *Aspergillus glaucus,* a common grain storage fungus. Grains free of internal storage fungi were surface sterilized before treatment with ^{14}C-malathion and fungal inoculation. Although ^{14}C-malathion was degraded in both sterilized controls and inoculated grain, control grain contained significantly more ^{14}C-malathion than inoculated grain after 6 months of inoculation.

Effect of Insecticide Distributon on ^{14}C-Malathion Metabolism.—The metabolism of ^{14}C-malathion in stored wheat in which 5 percent or 100 percent of the kernels were treated with the same overall amount of insecticide was investigated over a 12-month period. Results showed no difference in the metabolism of the insecticide in either treatment. During the 1-year incubation period, quantities of chloroform-soluble radiocarbon decreased while those of water-soluble and unextractable residues increased. Quantities of volatile radiocarbon reached a peak after 6 months of incubation.

Microbiology of Insect Pathogens

Many insect pests that infest stored grain and processed cereal products are susceptible to microbial insect pathogens such as certain bacteria, viruses, and fungi. These microorganisms are selective in their insect pathogenicity, do not pollute the environment, and are safe to humans and other mammals. Our research with these organisms involves basic and applied studies of the structure, physiology, and mode of action of selected bacterial and viral insect pathogens. These studies include the use of *B. thuringiensis* and granulosis virus to control the Indianmeal moth and other Lepidopteran pests of stored grains; structure, toxicity, and biosynthesis of the entomocidal protein of *B. thuringiensis;* insect tissue culture for *in vitro* determination of molecular toxicity; and measurement of differential toxicity between various *B. thuringiensis* isolates. Recent progress in this area includes the following.

Cloning of the Gene Responsible for Toxin Synthesis in *B. thuringiensis*.—The gene that codes for the entomocidal protein produced in the proteinaceous inclusion body of *B. thuringiensis* was isolated and cloned into the bacteriophage vector Charon 4A. One recombinant phage (C4K6c) produced antigenic protein that was the same size as the toxin and was toxic to *Manduca sexta* larvae. Subsequent cloning of restriction fragments from C4K6c in alternative vectors was used to yield plasmid probes for further localization of the structural gene for toxin protein in *B. thuringiensis* chromosomal and plasmid DNA. Hybridization studies indicated that a chromosomal gene had been cloned although an identical gene of plasmid origin was also present in recombinant DNA fragments.

Bioassay of *B. thuringiensis* Entomocidal Protein Using Cultured Insect Tissue.—Insect tissue cells grown in laboratory culture exhibit a response to *B. thuringiensis* entomocidal protein similar to that observed in the intestinal cells of insect larvae after ingestion by normal feeding. Cultured cells swell, become distorted in shape, and eventually burst much like the response of columnar midgut cells when larvae are exposed to the protein toxin. Thus, the laboratory bioassay of *B. thuringiensis* toxicity has been simplified by the use of cultured insect cells with no loss in specificity. Cell lines from three species of Lepidoptera and two Diptera are routinely carried for bioassay purposes and for studies concerning toxin biochemistry. A totally resistant cell line from the spruce budworm *(Choristoneura fumiferana)* was developed by continual incubation in the presence of toxin, and attempts were made to clone a fully sensitive cell line from the same species. These lines will be valuable in determining aspects of cellular physiology that are important for the development of *B. thuringiensis* strains that are more effective against pest insects.

Relationship Between *B. thuringiensis* Spore Coat and Crystal Protein Synthesis.—Two major classes of polypeptides were extracted from the spore surface of *B. thuringiensis* subsp. *kurstaki:* the 134,000-dalton protoxin that is the major component of the inclusion body and spore coat polypeptides similar to those found on *B. cereus* spores. Acrystalliferous mutants lacked a well-defined spore coat, and deposition of inclusion body protein seemed to correlate with inhibition of spore coat synthesis. The suggestion was made for the inclusion of *B. thuringiensis* subspecies as *B. cereus* varieties because of numerous criteria of relatedness.

Integrating Microbial Insecticides into Grain-Protection Programs

Research in this area is directed toward developing methods for using microbial insect pathogens to prevent and control insect infestations in stored grains and processed products. Included are studies of the susceptibility of populations of Indianmeal moths and almond moths to *B. thuringiensis*, evaluating the effects of commodity characteristics, storage environment, types

of storage systems on pathogen persistence and effectiveness, and studies of interactions between biology and behavior of the pest insect species and method of pathogen application. Recent progress in this area includes the following.

Pilot-Testing Methods of Applying *B. thuringiensis* to Grain.—A 3-year pilot-testing program to evaluate the performance of *B. thuringiensis* under farm grain bin conditions in Nebraska, Kansas, Oklahoma, Iowa, and Illinois is being concluded this year. This study includes comparisons of the efficacy of dust and wettable powder formulations, relative effectiveness of different water volumes for applying the wettable powder, and application in the auger at the time bins are filled versus application to the grain surface after the bins are filled. We are evaluating the uniformity, toxicity, and long-term performance of the bacterial deposits produced by the various treatment methods. We are also measuring the *B. thuringiensis* susceptibility of native populations of Indianmeal moths. Conclusive data are not yet available, but the results look promising. Moth populations have been reduced, although not eliminated; the two formulations have been equally effective and reduced water volumes have been as effective as the label rate. Native Indianmeal moth populations vary in susceptibility to *B. thuringiensis,* but most of them seem to be susceptible to the label dosage.

Evaluating Pest Management Strategies for Farm-Stored Grain

The on-farm capacity for grain storage has increased steadily during the past decade. U.S. grain producers faced with depressed grain prices have turned increasingly to storage of grain on the farm in anticipation of improved markets in the future. Currently, nearly two-thirds of the nation's grain supply is owned by individual farmers and stored directly on the farm. The quality of this grain and the measures taken to maintain its quality are critically important to the U.S. positions in world grain markets, to farmer income, and to consumer food costs. Research under this project develops storage systems and strategies for managing grain stored on the farm and documents the specific value of individual components of the system in maintaining the quality of grain in storage and preventing economic loss.

Establishing a Field Laboratory—This newly developed project requires both the use of simulated storage situations for preliminary evaluations and the further development of a field laboratory, consisting of a sufficient number of full-scale, farm-type bins and related equipment to provide for replication of selected storage strategies under real-world conditions. Contacts have been established with the Grain Bin Manufacturers Council of the Farm and Industrial Equipment Association to explore possible areas of cooperation in developing a field laboratory site at USGMRL.

Carbon Tetrachloride Assessment Team.—A report on the pesticide carbon tetrachloride (CCl_4) was prepared jointly by a USDA-STATE-EPA assessment team for presentation to EPA. Biological and economic information was developed on the use of $CC1_4$ in stored grain and milled products located in on-farm storage, off-farm storage, and in milling and processing plants. Additional data also were presented on alternative methods for controlling insects in stored grain, and user guidelines were suggested to reduce the hazards associated with the use of $CC1_4$-based liquid fumigants.

Pest Management in Farm-Stored Grain.—A leaflet (No. 569) has been prepared in cooperation with the Extension Service of USDA that highlights the steps farmers should take in preventing insect infestation of stored grain. The leaflet is based upon research findings of this and other laboratories and stresses the importance of cleaning harvesting equipment and grain bins, spraying bins with residual insecticides, storing only clean, dry grain, leveling the grain surface, using a grain protectant, using well-maintained storage bins, aerating the grain to control insects and molds, and making regualr inspections to assure that the grain is in good condition. The leaflet was prepared to help communicate the grain storage technology already available to those directly involved in the storage of grain.

Biology and Control of Fungi

Research is directed toward increasing our understanding of molds or fungi that grow in and cause damage in grain. We monitor fungal population changes along with physical and chemical changes in grain during storage at various temperatures and moistures. These studies include tests of grain during low-temperature or solar-heated drying as well as small-bin and laboratory-scale storage tests. Other variables being investigated are initial inoculum or mold spore load, storability differences among hybrids or varieties, and effects of mechanical damage. Preharvest fungal invasion of corn, as it affects quality and storability, is also studied.

Fungal Growth During Low-Temperature Corn Drying.—When corn with 27 percent moisture was being dried with solar-heated air at 4 cfm/bu, it was invaded by fungi that are generally not considered to be storage fungi. The cool, wet conditions in the corn

ahead of the drying front were ideal for the growth of field fungi. *Alternaria*, which is rarely found in corn kernels, had infected about 40 percent of the kernels during the 10-day drying period. *Fusarium moniliforme,* the most common field fungus in corn, also increased during storage. The dark growth of *Alternaria* was visible in cracks and on broken edges, contributing to a reduction of the market grade of the corn.

Competition Among *Aspergillus* Species in Stored Grain.—*Aspergillus glaucus* is the most commonly found storage mold in grain. Laboratory storage tests at 25°C and 85 to 87 percent relative humidity showed *A. glaucus* to colonize more corn kernels than *A. candidus, A. niger, A. flavus, and A. restrictus* when all were inoculated simultaneously. Tests in progress will identify further competitive relationships and grain damaging capabilities of these fungi. When freshly harvested corn with 17 percent moisture was kept in bins with a low airflow in an unheated building, *A. glaucus* was the only fungus that grew to a measurable extent. Within 4 weeks, 25 to 55 percent of the kernels were infected.

Field Infection of Corn by *A. flavus*.—Preharvest infection is an important source of contamination by aflatoxin, a carcinogen produced by *A. flavus*. Field tests showed relatively low infection rates in Kansas even when corn silks were inoculated with the fungus. No appreciable differences in susceptibility were observed among hybrids with different kernel types. In several years of testing, infection has been highest in corn ears with highest levels of insect damage and in seasons with hot, dry weather during the kernel-filling period.

ENGINEERING RESEARCH UNIT

Researchers in the Engineering Research Unit conducted investigations on (1) minimizing fuel energy required for grain drying, (2) measuring and controlling dust from grain handling, and (3) reducing damage to grain during handling. We summarize below recent progress in these areas.

Minimizing Fuel Energy for Grain Drying

Solar Drying of Grain.—We investigated the economic feasibility of solar collectors and the management and operating procedures that would reduce the labor requirements of such equipment. We developed a transfer strategy for batch, in-bin, grain drying at relatively high airflow rates and grain depths of 5 to 7 ft. The strategy provided adequate moisture reduction to average moisture contents of 13 to 15 percent. A solar collector surface area equal to that of the bin floor area provided enough supplemental heat to reduce grain moisture 1 percent below that removed by ambient air alone during the test period.

The solar heat, in-bin, grain-drying system reduced the energy-electrical input requirement by about 10 percent. The transfer strategy provides a management means of overcoming the problem of nonuniform distribution of airflow from fine material in wet grain, especially corn. Other advantages of the solar heat-transfer strategy include increased control over drying rate, increased drying capacity, reduced opportunity for mold growth, and the possibility of earlier harvest. It can also dry grain of higher initial moisture content.

We performed a comparative test in solar drying on two lots of field combine-shelled corn that were binned following harvest. One lot of 1,569 bu averaging 27.8 percent moisture content was stored in the solar heat bin system (SH). The second lot, consisting of 1,623 bu of a second hybrid from another field with an average moisture content of 21.5 percent, was loaded into a bin with natural air system (NA). The initial corn depth was similar in the two bins and averaged 7.5 ft. Air flow was also similar, with the initial rate 4.1 cfm/bu and the final rate about 4.8 cfm/bu. The test period was 11 days, with the NA fan turned off after 174 h while the SH fan (for the higher moisture) corn) operated for 251 h.

Corn samples in the NA test lot showed a 12.8 percent moisture content near the bottom and 16.0 percent at the surface, with an average of 14.2 percent when unloaded. The NA fan consumed 1,248 kWh of electricity or 0.83 kWh/bu for a 7.3 percent point water reduction, equivalent to 113 Wh/bu for each percentage point moisture reduction. Corn from the SH bin had a moisture content of 11.8 percent at the bottom and 16.5 percent near the surface, for an unloading average of 15.0 percent, a 12.8 point reduction. Energy consumption was 1,765 kWh, or 103 Wh/bu for each percentage point moisture reduction.

Wind-Powered Aeration System.—We evaluated a wind-powered aeration system. Cold grain temperatures during the winter months reduced insect population while warmer grain in the summer months allowed the insects to reproduce. We utilized cold air during the winter months to aerate the grain. We explored the merits of using wind power to pull air through grain by installing wind-powered ventilation devices in 15-ft diameter, circular steel bins. These devices provided

enough aeration to alter grain temperatures.

The advantages of wind energy ventilation systems are comparable to other grain aeration systems because they minimize temperature differences within the stored grain, thereby reducing moisture migration potential, especially in large bins of over 1,000 bu. Wind-powered ventilators provide a means for aerating grain without electrical energy but are dependent upon environmental conditions for effective operation.

Energy from Corn Dust.—Many grain dryers and irrigation pumps are powered by natural gas. Solar and wind energy may be useful in certain situations but, in many cases, gas is still required. Gas can be produced by such agricultural residues as corn stalks and grain dust. We conducted experiments on corn dust gasified with steam in a 5-cm inner diameter, bench-fluidized bed reactor. The gas was analyzed over a temperature range of 867 K to 1,033 K to examine the influence of temperature on gas composition, yield, heating value, and energy recovery. We found the gas yield to be extremely temperature dependent and increasing linearly from 0.13 m^3/kg at 867 K to 0.73 m^3/kg at 1,033 K. The heating value of the produced gas ranged from 9.4 MJ/m^3 at 867 K to 11.5 MJ/m^3 at 1,002 K. The principal components of the product gas were water, carbon monoxide, and carbon dioxide, which included more than 90 percent of the combusted gas. The remaining 10 percent consisted of methane, ethylene, and ethane. The energy recovery increased linearly from 8 to 55 percent over the temperature range studied.

Measuring Dust Generated During Grain Handling

Dust Control in Grain—We utilized the USGMRL elevator to study the effects of additives in reducing grain dust emissions. Three methods of measuring dust emissions were employed, including airborne dust concentration, quantity of tailing dust collected from air cleaners in the dust control system, and residual grain dustiness. We used high volume air samplers and the light attenuation levels of dust clouds to calculate airborne dust concentrations at the boot and head of a bucket elevator and inside overspaces. Additions of 0.05 percent animal fat (grain basis) sprayed on corn and wheat as the grain entered the boot of a bucket elevator resulted in an average 50 percent reduction in dust emission. These results were similar to that of another study using additives at a commercial (full scale) elevator.

Measuring Grain Velocity.—We tested a method of measuring grain velocity using a hand-held probe. The 2.5-cm square probe contained a pair of light-emitting diodes and phototransisters spaced 1 cm apart. Signals from the phototransisters were attenuated by light reflected from the passing grain kernels and were recorded on a digital oscilloscope. The velocity of grain kernels was determined by dividing the distance between phototransisters by the time between corresponding signals. Time was determined by an auto-correlation of the two signals. At a spacing of 1 cm, velocities up to 10 m/s could be measured. The probe was able to detect signals up to 15 cm from the grain stream through a plexiglas window. It could also be used to obtain a velocity profile of flowing grain by inserting the probe into a grain stream and recording signals at sequential depths within the grain stream.

Particle Size Distribution of Dust Cloud.—We developed a method for measuring the particle size distribution of a dust cloud suspended in a modified Hartman bomb. The modification involved mounting a HIAC sensor underneath a Hartman dispersion cup and providing a means to draw an air-dust sample through the center of the cup. Using this apparatus and technique, we analyzed a number of dust samples for particle size distribution. One set had been collected during a study to determine the maximum rate of pressure increase and the maximum pressure of grain dust in a 20-L bomb. Another consisted of dust samples from corn, wheat, milo, soybean, and oats collected at small, medium, and large commercial grain-handling facilities. A third set was a series of dust samples tested before and after dispersion in the 20-L bomb. In the last test, we found that the size of particles dispersed within the bomb was smaller than that loaded into the dust reservoir.

Use of Additives—We conducted a series of tests to study the effectiveness of water, deodorized soybean oil, and mineral oil as dust-controlling additives in large-scale, grain-handling operations of corn, wheat, and soybeans. All additives were sprayed on grain during transfer from one storage bin to another. The flow rates of the additives were regulated through a valve connected to a source of compressed nitrogen. We found that the additives were best applied by continuously spraying both the top and the underside of a grain stream at the first belt transfer point after the grain left the storage bin. In extremely cold weather, we found it necessary to heat the additives to reduce viscosity and achieve efficient spraying.

Soybean Oil as Dust Suppressant.—Between 0.03 and 0.10 percent by weight (grain basis) of soybean oil applied to all three grains and between 0.02 and 0.08 percent by weight of mineral oil applied to corn were

effective in reducing dust emission. The ability of mineral oil to control dust in corn was not reduced after 3 months' storage of the treated grain. The amount of oil needed for optimum effectiveness ranged from 0.02 to 0.05 percent. Adding 0.17 to 0.30 percent water by weight to corn was temporarily effective in controlling dust emission. The average weight loss of untreated grain from dust dispersion was approximately 0.14 percent each time it was handled but, when an additive was present, this loss was reduced to 0.035 percent or less. An application level of 0.3 percent water to corn reduced the gallery floor dust concentration by at least 80 percent, and an application rate of 0.03 percent soybean or mineral oil at the same location reduced the dust concentration by more than 90 percent.

Minimum modifications of the existing facilities were required to undertake these trials and, under normal conditions, the operation of an additive-spraying unit should be entirely automatic and require only periodic inspection to ensure proper mechanical functioning and flow rate.

Dust Explosion Research

Modeling Grain Dust Explosions.—Our work in 1982 involved both experimental and theoretical efforts toward modeling grain dust explosions in a 20-L spherical chamber. We used dimensional analysis to show that the volume cubic-scaling law must hold if the peak rate of pressure rise was to depend only on the radius of the explosion vessel, maximum explosion pressure, Lagrangian flame speed, and initial dust cloud density. We developed a thin-laminar-flame model that described the general features of the pressure evolution in a confined dust explosion but that did not contain detailed chemical kinetics. We developed a spatially uniform model, containing much more detailed chemical kinetics, which did not permit gas-dynamic motion of the reacting dust cloud. This was used to model the results of shock-tube studies of grain dust combustion. We developed a gas-dynamic, dust-combustion model, which included both detailed chemical kinetics and gas-dynamic motion. Our efforts to obtain numerical solutions of this model met with limited success because of computer limitations and, possibly, limitations of the code we were using to solve the partial differential equations of the model. Any future work along these lines should include much finer spatial zoning and a code specifically tailored to the equations to be solved.

Grain Dust Explosion Parameters.—Our contract work with the Grain and Feed Association involved measuring the peak pressures and rates of pressure rise from grain dust explosions in a 20-L spherical chamber. Values were measured for corn dust, wheat dust, milo dust, soybean dust, oat dust, cornstarch, wheat flour, and dust collected from an export terminal. These samples were also analyzed for heat of combustion, ash and moisture contents, specific surface area, and particle size distribution. Statistical analysis showed that the parameters determining peak pressure and rates of pressure rise were heat of combustion, dust concentration, and the specific surface area of the dust calculated from the measured particle size distribution. We redesigned the dust dispersion system on the 20-L explosion vessel built at USGMRL. We have made high-speed photographs of the dust cloud from the new system but have only done preliminary explosion testing.

The risks of dust explosions in grain processing and handling facilities have been compared to other types of man-made risks, and both the magnitude and frequency of the occurrence of these types of hazards have been examined simultaneously. To discern if a trend of increasing frequency exists, we compared data from 1958 to 1968 with that from 1968 to 1978. We found that the loss of life from dust explosions had increased drastically in the United States in the later period.

Reducing Damage to Grain During Handling

Design and Use of Grain Spreaders.—We investigated the bulk properties of grain as they are affected by self-propelled, rotational type, grain spreaders. We used a self-propelled, rotational, 4-trough grain spreader constructed at USGMRL and two commercially available rotational type grain spreaders to fill a bin with wheat, corn, and grain sorghum. The grain was choke-fed through an orifice to the spreaders. Under this operating condition, the uniformity of fine material distribution in the grain mass was generally the same for bins filled with or without a spreader. Damage to the grain during bin filling was lower when it was choke-fed through an orifice to the bin than when it was transferred through a conventional spout. When we used the 4-trough spreader, the surface of the grain in the bin was reasonably level, but the dustiness of air in the bin was greater than when a spreader was not used. The bulk density and airflow resistance of grain transferred into a bin by spreaders were higher than those for grain transferred without a spreader. At an airflow rate of 4.6 $m^3/(min \bullet m^2)$, the power required to move air through the grain transferred into a bin by spreaders was 55 to 150 percent higher than that for grain transferred without a spreader.

Bulk Density of Grain Dust—We also investigated

the bulk density characteristics of grain dust. By utilizing available information on pressure density relationship of grain dust, we developed models to predict grain dust density distribution and weight in containers under various pressures and in free-standing piles. We concluded from the investigation that (1) The weight of a self-packed dust column increased linearly as the depth increased; (2) The dust-holding capacity of a given container increased linearly as the mechanical pressure increased; (3) At the same pile angle, the weight of a grain dust pile increased exponentially as the base diameter increased; and (4) The effect of moisture content on bulk weight of grain dust was small. These models were applicable to such other compressible materials as forage and hay. Results enabled us to determine the dust-holding capacity of a container and to estimate the pressure requirement for a container to hold a desired amount of dust.

Grain Moisture Content Effect on Flow Rate.—We conducted tests to determine the effect of moisture content on the flow rate of grain through various sizes of orifice. The two sets of orifices used were 5-in to 10-in rounds and 5-in to 9-in squares at size increments of 1 in for both sets. Moisture contents of corn tested were 12, 15, 19, and 22 percent wet basis. The flow rates ranged from 833 to 926 bu/h for a 5-in-round orifice and from 5,161 to 6,467 bu/h for a 10-in-round orifice, depending upon the moisture content. For the same size orifice, the flow rate of corn increased as the moisture content decreased.

Grain Flow Regulator—A grain flow regulator and decelerator was designed in 1981. The purpose of this apparatus was to reduce the dustiness and impact damage to grain during loading. The apparatus consisted mainly of a hopper with gate valve, decelerator, grain level sensor, proportioning controller, and a servo-positioning motor. We received the major components for the apparatus in August and tested them for their response to the grain level changes. The results indicated to us that the response was adequate, and the apparatus will be constructed next year.

Computer Facilities

The computer facilities provide services and resources to all researchers at USGMRL. The present centralized facilities include two minicomputers with three terminals and various mass media storage. The older minicomputer is primarily used to gather data from nonstandard peripheral devices as well as standard sources. Interface hardware for the nonstandard devices is built at the facility, and assembly level device drivers are written to incorporate the device into the standard disk-operating system. The larger minicomputer is available for researchers to carry out statistical analysis, data manipulations, graphing, and to store large amounts of data. Both computers have Cathode Ray Tubes (CRT) for output with extensive, in-house developed, graphical capabilities. These assembly level graphical capabilities have been incorporated into high-level languages so that novices can easily use them. Program assistance is available for researchers, and many programs have been written for the various laboratory personnel. Future plans are to expand the newer minicomputer and place CRT's in strategic locations so that computing power will be available to the researchers in their laboratory on demand. Several other minicomputers and microcomputers are used throughout the laboratory as intergal parts of special machines and as small stand-alone units. Diagnosis of hardware problems and assistance in the application of softwares are available on request for the researcher.

GRAIN QUALITY AND END-USE PROPERTIES UNIT

Research activities in the Grain Quality and End-Use Properties Unit are concerned with (1) identifying physical and structural characteristics and chemical components that govern or are associated with functional properties; (2) developing, improving, and evaluating methods and instruments that can be used to objectively, rapidly, and accurately characterize and evaluate grain in domestic and export marketing channels; and (3) cooperating with plant breeders throughout the Great Plains and with agronomists, plant physiologists, entomologists, and biochemists at KSU by providing milling, baking, and biochemical expertise and support for selective projects of mutual interest.

Specifically, researchers (1) Determine and evaluate the functional (milling and breadmaking) properties of early generation and potentially new hard winter wheats bred for the Great Plains and evaluate the earliest feasible generation of hard winter wheats bred for genetically high protein content. Kjeldahl (protein) analytical equipment and the 10-g mixograph, together with micro- and macro-milling and breadmaking equipment, are employed to determine functional properties of about 1,600 plant breeders' samples (10 to 1,500 g); (2) Develop new methods and techniques of determining chemical, milling, breadmaking, physical-chemical, and biochemical properties of hard wheats; (3) Develop energy-conserving baking

methods and high-protein and nutritionallly improved breads; and (4) Develop physical and biochemical functionating and reconstituting techniques to relate functional (breadmaking) to biochemical properties of wheat-flour components and to determine the chemical fractions and components of wheat responsible for quality differences.

After literally taking the flours apart, corresponding gluten-protein, gliadin- and glutenin-protein and their fractions, modified and unmodified, and other wheat flour fractions of good and poor quality wheat flours are interchanged, one at a time and in combinations, in the reconstituted flours. Fractions and reconstituted flours are characterized by physical, biochemical, and breadmaking techniques. Research during the past year has been in the following areas.

Determining and Evaluating Functional Properties of Potentially New Hard Winter Wheats

About 350 samples, each aout 1,500 g, of agronomically promising new varieties and recent releases of hard winter wheat were characterized and evaluated in terms of their functional properties including wheat hardness; bolting properties and flour yield; flour ash; dough mixing, oxidation, and water requirements; bread crumb grain and color scores; and loaf-volume potential. About 37 percent of the samples had good milling, chemical, breadmaking, and physical dough properties. Leading commercial wheat varieties of tomorrow are among them, and 47 of them, in addition, had genetically high-protein contents of 1 to 4 percentage points more than the controls.

About 990 small samples (40 to 100 g) of early generation progenies of hard winter wheats were micro-milled and evaluated for milling. We subjected each sample of flour to certain analytical, water-absorption, and mixogram tests. About 595 (60 pct) had promising overall functional properties. Also, 274 of the 595 promising ones had 1 to 3.9 percentage points, and 108 had 2.0 to 3.9 percentage points more flour protein than their controls.

From 1975-82, average wheat yield in Kansas (31.3 bu) was 7.1 bu greater, and average wheat protein content (12.1 pct) was 0.4 percent higher than the corresponding averages for the 1960's. Thus, the gradual decline in wheat protein content apparently has been halted and reversed during the past 8 years by high-protein 'Eagle' and other relatively new Kansas varieties of hard winter wheat. Furthermore, during the 6 years 1977-82, average wheat yield in Kansas (31.9 bu) was 14.8 bu greater than and average wheat protein content (12.3 pct) was about equal to the corresponding averages for 1948-59. Without the new varieties of the 1970's, wheat protein content probably would have continued to decrease to less than 11 percent.

New 'Dawn' Wheat

'Dawn' wheat, *Triticum aestivum* L. em. Thell., C.I. 17801, is a hard red winter wheat cultivar developed by the Colorado Agricultural Experiment Station and tested and released by the South Dakota Agricultural Experiment Station. 'Dawn' was derived from the cross II21031/Trapper//CO652363. The pedigree of CO652363 is Warrior/2/Kenya 58/Newthatch/2*(Cheyenne/Tenmarq/Mediterranean)/Hope/3/Parker. 'Dawn' has good milling qualities and bakes as well or better than 'Scout 66' and 'Gage.' It has a longer bake-mixing time, stronger dough characteristics, lower water absorption, greater loaf volume, and better grain and texture than 'Scout 66' and 'Gage.'

New 'Rita' Wheat

'Rita' wheat *(T. aestivum* L. em. Thell.) C.I. 17799 is a hard red winter wheat cultivar developed by the South Dakota Agricultural Experiment Station. 'Rita' was derived from the cross Seu Seun/Denton 8//Westmont/3/SD6689, Ponca//3*Cheyenne/Kenya 58/Newthatch//2*(Cheyenne/Tenmarq//Mediterranean/Hope). It has good milling and baking qualities. It also has stronger bake-mixing time and stronger dough characteristics than 'Scout 66.'

New 'Arkan' Wheat

'Arkan' hard red winter wheat *(T. aestivum* L. em. Thell.) KS79H69, was developed cooperatively by the Kansas Agricultural Experiment Station and ARS-USDA. Its pedigree is Sage/Arthur. The cross was made at the Fort Hays Branch Experiment Station during the winter of 1970-71 by R. W. Livers and was distributed to Kansas growers in 1982. Based on composite grain samples from the regional and state performance test, 'Arkan' has very good overall hard-wheat milling and breadmaking properties. It has a somewhat longer than medium mixing time and a very good loaf volume potential. Grain and flour protein contents of 'Arkan' have averaged 1 percent more than those of 'Newton.'

Reselection of Hard Red Winter Wheat Cultivar 'Lancota' for High Grain Protein Content

Developing high-yielding wheat (*T. aestivum* L.) cultivars with increased grain protein content is an important goal of hard wheat breeders. High grain protein content is desirable for baking quality and nutri-

tional purposes. The wheat cultivar 'Lancota' has genetic potential to produce grain with higher protein content than most other cultivars grown in the hard winter wheat region. It has not consistently expressed full potential for grain protein content outside its area of development. We conducted experiments to determine genetic variability for grain protein content in 'Lancota' and to utilize that variability to select genotypes with high grain protein content. Approximately 1,600 lines were screened to 37 high-protein selections that varied in yield, test weight, flour-mixing time, blooming date, height, and reaction to wheat soil-borne mosaic virus (WSBM). Nine promising selections (KS80476, KS80478, KS80480, KS80488, KS80490, KS80491, KS80497, KS80499, and KS80500) had grain protein advantage over 'Lancota' of 0.5 to 1.0 percent and equaled or exceeded 'Lancota' in yield or test weight. Those selections were resistant to WSBM and satisfactory or better in mixing properties than 'Lancota.' The highest protein selection (KS80496) had a mean protein advantage of 1.5 percent over 'Lancota' but exhibited a short mixing time of 1 7/8 min. The absence of correlation between some years indicated strong environmental influence on protein content. We concluded that adequate genetic variability existed in the high grain protein cultivar 'Lancota' to select lines that express the high-protein potential better than the original cultivar outside its area of development.

Proton Magnetic Resonance Studies of Barley and Wheat Thionins: Structural Homology with Crambin

The ubiquity of thionin homologues throughout the plant world raises interesting questions about the evolutionary and genetic connections among the species from which they are extracted. Five thionins of known sequence, from barley and wheat, have been investigated and compared by ^1H NMR spectroscopy at 600 MHz. From their spectral characteristics, we concluded that the five proteins have very similar, nonrandom conformations in ^2H_2O solution. Moreover, on the basis of selective nuclear Overhauser experiments at 300 MHz, features of their secondary and tertiary structures are shown to be similar to those of crambin, a related, hydrophobic protein extracted from seeds of the crucifer *Crambe abyssinica*. The strong compositional homology of the thionins facilitates the assignment of methyl and aromatic resonances as only a few residues are replaced and these are at known sites. Substituting leucine for an isoleucine does not affect significantly the local magnetic environment, which suggests that those isomeric side chains easily accommodate the same spatial constraints. A fast hydrogen-deuterium exchange is observed at pH 6.25, 25°C. This indicates that, although of folded conformation, the thionins are structurally flexible polypeptides that efficiently expose all amides to the solvent.

Primary Structure of a Purothionin from *T. monococcum*, a Diploid Wheat

Extraction of purothionin from diploid wheat *T. monococcum* yielded two proteins, one of which was present in very small amounts. The major *T. monococcum* purothionin had an amino acid sequence identical with that of the β-purothionin of *T. aestivum* (hexaploid bread wheat). Because *T. monococcum* contains the wheat A genome, the structural gene coding for the β-purothionin comprises a part of the A genome. There have been no observable changes in the DNA comprising either the β-purothionin gene of *T. aestivum* or the purothionin gene of *T. monococcum* since *T. monococcum* (or its wild equivalent, *T. boeoticum*) hybridized with the diploid wheat B genome progenitor and started the evolution from diploid to allohexaploid wheat. All of the investigated characteristics of the purothionin-like protein isolated in small amounts (Tm_a protein) suggested that it was essentially identical in amino acid sequence with the *T. monococcum* purothionin. It may be a dimerized form of β-purothionin.

Three-Hour Method for Hydrolyzing and Determining the Amino Acid Composition of Submicrogram Amounts of Cereal Proteins and Peptides

Methods have been developed for quantitatively hydrolyzing proteins in 60 min and for analyzing the amino acid compositions of the hydrolysates by HPLC in an additional 51 min. The amino acids were detected by the fluorescence of their o-phthaldialdehyde (OPA) derivatives, and 10 pico moles of each of the commonly occurring α-amino acids could be reliably determined. The OPA derivatization method yields amino acid derivatives that are stable for a least 2½ h, and the HPLC method gives a better separation than previously published methods. This sensitive, amino acid analysis method, together with an HPLC method for separating enzymatically produced peptides, has allowed us to conduct amino acid sequence studies on milligram amounts of cereal thionins.

Effect of Environment- and Genetic-Related Alterations of Physical and Functional Properties of Wheat Grain on the Stability of the Gliadin Proteins as Detected by Polyacrylamide Gel Electrophoresis (PAGE)

Wheat samples from homozygous plants that were derived from widely diverse germplasms appeared to be a mixture of cultivars because of large variations in kernel size, shape, and color. PAGE patterns of the gliadin proteins of those physically different components were identical. Thus, identification of wheat varieties by kernel characteristics alone is not valid. In a mixture of two cultivars, the minimum amount of one that can be detected by PAGE is 5 to 10 percent. When wheat was germinated for 44 h or severely frosted during maturation, PAGE patterns of the gliadin proteins were unaltered even though dough mixing properties and loaf volume were greatly impaired. Thus, conditions that rendered the flours practically nonfunctional did not affect the chemical constitution of the gliadin proteins.

Computer-Assisted Method for Identifying Wheat Cultivars from Their Gliadin Electrophoregrams

A computer program has been developed to aid in identifying wheat cultivars by comparing their gliadin electrophoregrams with those of standard varieties stored in the computer memory. The main output of the program is a relative percent similarity plot, which shows the similarity of the electrophoregram of the cultivar in question to that of each of the standard cultivars. In addition, the program lists the names of those cultivars, whose electrophoretic patterns are most similar to that of the "unknown" in order of decreasing similarity. The weighting factors used for calculating similarities are listed and explained, and examples are given for identifying 'unknown' cultivars.

Various Oils, Surfactants, and Their Blends as Replacements for Shortening in Breadmaking

Various concentrations of 14 different oils alone and in blends with each of two surfactants were studied to determine which oils might be superior in breadmaking. We determined the amount of oil, sodium stearoyl-2-lactylate (SSL), or diacetyl tartaric acid esters of mono- and diglycerides (DATEM) needed to reach the half-way volume of bread between those for no added shortening (899 cc) and 3 percent added shortening (1,000 cc), and then blended those half-way amounts of oil and DATEM or SSL to determine whether synergistic effects occurred. Six grams of each oil alone was required to give the loaf volume equal to that for 2 percent shortening in the formula. The half-way volume for most of the oils was 2 percent, for SSL 0.2 percent, and for DATEM 0.35 percent. When 2 percent of each oil plus 0.2 percent SSL or 0.35 percent DATEM was added in the formula, volume of bread was equal to or greater than that for the control containing shortening. Adding 2 percent of each oil plus only 0.1 percent SSL or 0.2 percent DATEM yielded loaf volumes equal to or greater than that of the shortening control. Thus, the mixture of oil and surfactant produced synergistic effects. The availability, lower cost, and ease of handling the oils, together with the low concentration of a single surfactant (0.1 pct SSL or 0.2 pct DATEM), are incentives for the baking industry to convert to the use of oils.

Optimized Breadmaking Method After 43 Years

An analytical, optimized, straight-dough, experimental, breadmaking method was described by Finney and Barmore in 1939 and 1941 to show loaf-volume and crumb-grain potentials and other functional properties. Its application to the evaluation of many varieties of wheat harvested from 4 to 5 crop years was later published by them. That test is as practical and useful today as it was when described more than 43 years ago. In recent years, however, several modifications of the breadmaking method have increased its versatility, simplified its formula, and increased its potential precision. For example, ascorbic acid, for the most part, effectively replaces potassium bromate; and because it is its own buffer against overoxidation, nonfat dry milk or Ardex 550 are no longer needed in the breadmaking formula. The optimized breadmaking method now includes formulas with or without sugar. Optimized breads are made when fermentation times vary from 180 to 70 min, with or without sugar in the formula. The method includes proofing to time only after the appropriate proof height has been established. Those relatively recent modifications are integrated into the optimized breadmaking method.

Water Binding of Wheat Flour Doughs and Breads as Studied by Deuteron Relaxation

Water mobility in wheat flour doughs and breads was investigated by deuteron relaxation using pulsed NMR. Water was replaced by D_2O in dough and bread at different concentrations. Mixograms indicated that wheat flour associated more strongly with

D_2O than it did with H_2O. Varying the D_2O:H_2O ratio of flour doughs had no effect on the longitudinal (T_1) or transverse (T_2) relaxation times of deuteron. Hard wheat and soft wheat flour doughs showed similar increases in T_1 and T_2 with increasing moisture content. Staling of bread crumb was accompanied by decreased T_1 and T_2, indicating an overall decrease in water mobility and an increase in water binding. The decrease in water mobility of bread crumb with storage time was independent of reduced moisture content.

ECONOMIC RESEARCH SERVICE

National Economics Division

Research activity of this unit encompasses the economic evaluation of a wide range of subjects related to producing and marketing grain and grain products. General research areas include grain quality, production costs, storage, marketing margins, and transportation.

Main objectives of these economic evaluations are (1) to provide economic assessments of new technologies and approaches to grain production and marketing; (2) to analyze the efficiency of assembling, processing, and distributing grain and grain products; (3) to conduct supply-demand analyses; (4) to estimate costs of producing and marketing grains and grain products, including white pan bread; and (5) to provide quick analyses of current topics.

Basic to the research efforts of this group, headquartered in Washington, D.C., is the interdisciplinary approach and environment afforded by USGMRL. This unit works in close cooperation with USDA's ARS personnel as well as with personnel at KSU. Research during the past year has been in the following areas.

Economic Evaluation of Solar Collectors for Agricultural Uses

Alternative technologies and designs of multipurpose, solar collector systems are evaluated in terms of payback and other economic performance measures. Technological progress is monitored, and estimates of potential agricultural uses are made to predict the role of solar as an alternative energy. Special attention is given to problems associated with the introduction of homemade collectors, specifically the need for value certification for lending and tax credit purposes.

Costs of Owning and Operating Grain-Handling Facilities

Costs of constructing grain-handling facilities designed to load unit trains are estimated to meet anticipated growth in grain exports the remainder of this century. Various levels of operation and economies of size also are evaluated for various regions of the United States.

White Pan Bread Marketing Spreads

The National Economics Division is responsible for determining white pan bread marketing spreads. These spreads are a part of the Division's long-term effort to monitor the performance of the U.S. food marketing system. Quarterly reports are prepared at USGMRL for release in Washington, D.C.

VISITORS TO THE U.S. GRAIN MARKETING RESEARCH LABORATORY

The Grain Marketing Research Laboratory was host to hundreds of visitors during FY 1982. Our register listed guests from 33 states and the District of Columbia and from at least 58 foreign nations. They included educators, scientists, legislators, farmers, processors, and students; they came to discuss, to learn, to teach, to look, and to work. They were curious, pleased, surprised, and amazed; we trust they were not disappointed. We were more than pleased to have them come, for we firmly believe that everyone benefits from these interactions: our visitors, through acquisition of information regarding the laboratory, its facilities and its activities, and we, through the broadening experience of contacts with individuals with differing background but similar interests.

Many visitors came in groups under the sponsorship of the Kansas Wheat Commission in cooperation with the U.S. Wheat Associates. The USDA Foreign Agricultural Service was also instrumental in arranging visits, as were KSU's Department of Grain Science and Industry, the Food and Feed Grain Institute, and the International Grains Program and the Group for Assistance on Systems Related to Grain After Harvest. Members of these groups had an abiding interest and

concern in international trade in wheat and in the storage of wheat and other grains both in the United States and in other countries as well as in research in these areas. Through these face-to-face contacts, our visitors gain first-hand knowledge of our past and current efforts, and we learn of the advances made and challenges facing them in their homelands. These visitors were from Central and South America, the Orient, Southeast Asia, the Near East, and the Magreb countries and other African nations with which we have actual and potential grain trade ties.

We were also pleased to host scientists and students who attended scientific society meetings at USGMRL; distinguished researchers who came to our Laboratory specifically to consult our scientists and discuss in-depth subjects of mutual interest; farmers and growers with broad interests in production, marketing, and utilization of grain; and millers, bakers, and allied trade personnel from private companies. Last, but by no means least, we welcomed individuals and groups representing the general public. We were more than happy to acquaint them with the objectives and functions of the Laboratory, in short, our role in the grain industry.

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(3) Field laboratory interactions to advance grain research
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*John S. Nickel	Research assistant
*Melinda J. Otto	Research assistant
*Ronald E. Schulze	Research assistant
*William E. Speirs	Research assistant
*Steven Z. Whetzel	Research assistant
*Jonathan P. Haliscak	Graduate research assistant
*Dr. Daizo Koga (Japan)	Post doctoral research associate
*Dr. Yoichi Aso (Japan)	Post doctoral research associate

Engineering Research Unit

Dr. Fang S. Lai	Research leader and research chemical engineer
Nelva H. Wilcox (retired)	Secretary
Dr. Cheng S. Chang	Agricultural engineer
Harry H. Converse	Agricultural engineer
Charles R. Martin	Agricultural engineer
Duane E. Walker	Electronic engineer
Robert Rousser	Instrument maker
Larry E. Shackelford	Engineering technician
George M. Wyatt	Engineering technician
*Seble W. Afework	Research assistant
*David F. Aldis (resigned)	Research assistant
*Tara S. Cupps (resigned)	Research assistant
*Brenda L. Lewis	Research assistant
*Jeanne E. Streeter	Graphics technician
*Dr. Ronald S. Lee	Professor
*Dr. H. Tanaka (Japan)	Visiting scientist

Grain Quality and End-Use Properties Unit

Prof. Karl F. Finney	Research leader and research chemist
Betty J. Fair	Secretary-stenographer
Dr. Bernard L. Bruinsma	Research chemist
Dr. Berne L. Jones	Research chemist
Dr. George L. Lookhart	Research chemist
Merle D. Shogren	Research food technologist
Lerance C. Bolte	Food technologist cereal
John D. Hubbard	Chemist
Bernadine M. Eichman	Biological technician
Michael H. Klinker	Agricultural research technician
*Margo S. Caley	Research assistant
*D. Blake Cooper (resigned)	Research assistant
*Marilyn B. Fox	Research assistant
*Tresa D. Jones	Research assistant
*Donna Schenck-Hamlin	Research assistant

Economic Research Service

Dr. Walter G. Heid, Jr.	Agricultural economist
Dr. L. D. Schnake	Agricultural economist
Margie L. Burk	Clerk-typist
*Karen D. Stuart	Research assistant
*Errol V. Williams	Research assistant

Maintenance Staff

Chester D. Little	Air conditioning mechanic-foreman
Robert L. Welfringer	Air conditioning mechanic
Terry B. Cassity	Electrician
Donald D. Brill	Custodian
Lacy Lowery	Custodian
Kerwin K. Crabs	Maintenance worker

*In cooperation with the Kansas Agricultural Experiment Station, Manhattan.

NOTES

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